

# SOIL SURVEY OF THE IMPERIAL AREA, CALIFORNIA.

[EXTENDING THE SURVEY OF 1901.<sup>a</sup>]

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## LOCATION AND BOUNDARIES OF THE AREA.

The area covered by this survey lies in the extreme southern part of San Diego County, itself the southernmost county in California. The country is desert, and is unique in that it is depressed below sea level.

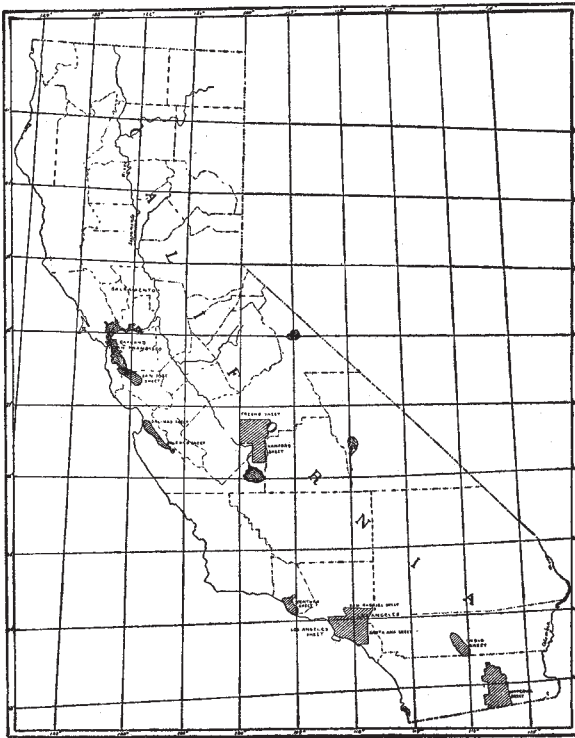


FIG. 59.—Sketch map showing location of the Imperial area, California.

A survey of a part of this region (170 square miles) was made in 1901, and a report thereon published in 1902. This area has been added to the 914 square miles surveyed the present season and the two published

<sup>a</sup> For the first report on this area with map covering 170 square miles see Field Operations of the Bureau of Soils, 1901, p. 587.

in one map on a scale of one-half inch to the mile. This map, covering about 1,084 square miles, embraces all of the irrigable land in the Imperial country in the United States.

The area extends from the international boundary line on the south, along which line the elevation corresponds to about sea level, to the badly alkaline lands of the Salton Sink on the northwest. It is bounded on the north by the San Bernardino Mountains, while on the east and west the limits are formed by sand-dune areas, too rough and broken to be economically prepared for irrigation. The area surveyed has a length of 47 miles north and south and a width of 24 miles east and west.

The Southern Pacific Railroad crosses the northern part of the area, with a branch from Old Beach to Imperial just completed. The nearest town of note is Yuma, Ariz., situated 60 miles to the east. San Diego, on the coast, is 115 miles distant due west, but there is no direct railroad connection with that place.

Two maps accompany this report, one showing the area and distribution of the different types of soil, and the other the condition of the soils as regards alkali.

The base map used in the soil survey is made up in part of two surveys known as the Rockwood survey and the Eastside survey, made by the California Development Company, supplemented by plane-table traverse work. An examination of the base will show that there are discrepancies between the two surveys. The strip of "no man's land," 2 miles wide, extending from R. 14 E. to R. 15 E., represents the discrepancies between the two surveys at this point.

The failure of the two surveys to check up is explained in this way: In 1854, shortly after California came into the Union, a land survey was made of this part of the delta. The Mexican boundary was not then well established, so that this survey extended only to the line between T. 16 and T. 17 S. Later, in 1892, after the boundary commission had put up the continuous line of monuments marking the southern line of our possessions, the fractional part of the row of township 17 south was surveyed.

When, in 1900, the California Development Company began selling water stock for the public land they easily found the corner stakes of the fractional townships 17 south, while the stakes of the old 1854 survey were nearly all gone. This 1892 survey was therefore extended north of the line between townships 16 and 17 south, to include the land between the two rivers and to the north side of T. 14 S. As this survey was being made, natural features were encountered, shown by the notes of the Government survey of 1854 (which were in the possession of the surveyors of 1900) indicating that the survey they were making did not correspond with the Government survey of 1854 by 2 miles or more. This survey was then stopped, and by locating all the natural points possible from notes of the survey of 1854 the Eastside

survey was made. This Eastside survey is as nearly as possible a reproduction of the original Government survey, and is the only legal one.

The original Government survey made each township about  $6\frac{1}{2}$  miles square, instead of the usual 6 miles square, so that there is a good deal of excess land in each township. Since section stakes could not be found except in rare instances, all this excess in each township was thrown to the north and west, making the sections along the northern and western sides of the townships about one-third larger than the ordinary sections.

As the erroneous survey of the country between the two rivers was being made, settlers were filing upon the land, and when the error was discovered most of the land had been taken up. A resurvey of the country will have to be made. This has been ordered with the injunction that the old township lines be followed. This discrepancy in the surveys has caused great confusion, has been an obstacle to the development of the country, and will doubtless yet be the cause of much litigation.

#### CLIMATE.

The climate of this part of the Colorado Desert has long been the subject of harrowing tales of scorching heat and blinding sand storms. It is true that the summers are long and excessively hot and that there are occasional violent sandstorms, but on the whole the climate is not a hindrance to the successful cultivation of the soil. Partial yearly records of temperature kept at Imperial show that the summer temperature is rarely above  $125^{\circ}$  F., and that  $19^{\circ}$  above zero is about the minimum for the winter. The atmosphere at all times is extremely dry, so that  $125^{\circ}$  is not more oppressive than  $100^{\circ}$  in the more humid parts of our country. In the spring and occasionally throughout the year strong west winds sweep the valley and are the cause of disagreeable dust storms. Throughout February, March, and a part of April these occur frequently and interfere somewhat with farm work, being so severe in some instances as to make working in the field impossible. As the country is settled, however, and trees are planted the force of these storms will likely be broken and their injurious effects diminish.

The mean annual rainfall is very slight, being estimated at less than 3 inches. This mostly occurs at long intervals as heavy rainstorms. In December, 1902, while this survey was being made, there fell in two days and one night  $1\frac{3}{4}$  inches of rain. Much of this sank into the soil, but enough ran off the surface to make a raging torrent of the Salton River, which was dry before the rain. The rainfall can not be depended upon, however, even as a supplement to irrigation, since its irregularity makes it wholly unreliable. Aside from an occasional rainy or windy day the winter climate is almost perfect. Except for

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the December rain mentioned above there were no days from October to February of the winter of 1902-3 that were not suitable for field work.

The utilization of this desert region has been a matter of considerable study during recent years, and the feasibility of the introduction of new crops, possibly from northern Africa, has led to a comparison of the climatic conditions of the two regions, using the data for Yuma, Ariz., the nearest available Weather Bureau station to the Colorado Desert, as a basis for comparison. It is too generally supposed that the conditions are very similar. Means, in Bulletin 21 of this Bureau, discusses this question quite fully. He says:

The climate of Egypt is arid. Over the greater part of the country there is practically no rainfall, and in no part is there sufficient rainfall to produce crops without irrigation. The average precipitation at Alexandria is 8.26 inches. At Port Said it is 3.49 inches; at Cairo, 1.06 inches. In upper Egypt, south of Cairo, there are no observations on the amount of rainfall, so that no exact figures can be given. There is, however, less rainfall than at Cairo.

The average temperature is high. The coolest portion of Egypt lies along the coast of the Mediterranean, and the temperature increases as one proceeds south. The following table gives the normal monthly and annual temperature of Alexandria and Cairo, together with normal temperatures at a number of points in the United States for comparison:

*Normal monthly and annual temperatures.*

Month.	Alexan- dria, Egypt.	Cairo, Egypt.	San An- tonio, Tex.	Mont- gomery, Ala.	Yuma, Ariz.
	° F.	° F.	° F.	° F.	° F.
January .....	58.8	55.0	51.5	48.3	54.1
February .....	59.4	58.5	55.8	52.7	58.8
March .....	62.1	63.1	61.9	57.0	64.5
April .....	65.8	70.3	70.1	65.4	69.8
May .....	70.7	75.2	74.9	72.8	77.2
June .....	75.6	81.0	80.7	79.4	84.9
July .....	80.1	84.0	83.3	81.5	91.5
August .....	79.9	82.4	82.2	79.8	90.7
September .....	76.5	77.2	77.5	75.6	84.4
October .....	73.2	73.9	69.7	65.2	78.0
November .....	68.9	65.1	59.0	55.2	61.9
December .....	62.6	58.3	54.9	49.6	56.0
Year .....	69.5	70.3	68.5	65.2	72.2

The temperature at Alexandria is normally lower than that at Cairo, and is more uniform, the winters being warmer and the summers cooler. There is probably no place in the United States where the temperature conditions correspond exactly with those in Egypt, but a careful examination of the records of the Weather Bureau reveals the fact that a zone through the southern tier of States, extending from San Antonio, Tex., eastward through Montgomery, Ala., has a normal summer temperature very close to that of lower Egypt. It has been generally supposed that the climate of the country around the mouth of the Colorado River and extending up into the Colorado River Valley in Arizona and California is very similar to the climate of Egypt. Such, however, is not the case. Normal temperatures from

Yuma, Ariz., are included in this table, from which it will be seen that there is a great difference between the temperatures of the two countries. Upper Egypt, no doubt, has a desert climate similar to that of Yuma, but meteorological records have not been kept in that part of the country.

The climate of Egypt may be described as subtropical. Slight frosts occur at Cairo and over portions of the Delta and middle Egypt, but upper Egypt and a portion of the Delta close to the Mediterranean Sea are said to be frostless. Oranges, date palms, and other subtropical fruits can be grown throughout the country.

Lying as Egypt does in the midst of the greatest desert area in the world and having so light a precipitation, it has been generally supposed that the climate is that of a desert—that is to say, that the atmosphere is normally very dry. So far as can be said, in the absence of continued scientific observations, upper Egypt and a portion of middle Egypt have a climate of this type; but the greater part of Egypt and that part in which cotton—the chief agricultural export—is grown has a climate very different from that of a desert. During the greater part of the year the prevailing wind is toward the south, blowing from the Mediterranean Sea to the land. This wind in its passage over the sea becomes charged with moisture, and thus gives to the atmosphere of Egypt a much higher relative humidity than is found in a true desert climate. The following table gives the mean monthly and annual relative humidity at two stations in Egypt and at a number of places in the United States:

*Mean monthly and annual relative humidity.*

Month.	Alexan- dria, Egypt.	Cairo, Egypt.	San Antonio, Tex.	Okla- homa, Okla.	Mont- gomery, Ala.	Atlanta, Ga.	Yuma, Ariz.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
January .....	68.0	66.4	65.6	74.5	75.3	76.4	45.4
February .....	67.0	60.4	63.8	73.0	74.7	73.9	43.8
March .....	68.0	58.0	62.1	68.3	68.8	68.6	43.0
April .....	69.0	52.0	67.7	65.3	64.8	62.4	35.1
May .....	69.0	50.1	69.6	73.0	66.8	65.8	36.7
June .....	72.0	50.9	67.3	73.2	70.1	71.1	34.7
July .....	75.0	51.8	64.0	71.3	76.0	76.3	42.8
August .....	73.0	57.5	65.2	68.8	73.1	77.9	47.7
September .....	69.0	65.0	68.8	67.8	74.0	75.2	44.7
October .....	68.0	68.5	63.7	64.5	69.0	68.4	46.2
November .....	67.0	69.5	65.3	71.0	72.7	73.3	43.3
December .....	68.0	71.1	62.8	74.1	75.6	75.6	51.4
Year .....	69.4	60.1	65.5	70.4	72.2	72.1	42.9

There is no place in the United States, so far as records are available, where the normal relative humidity is that of Cairo, Egypt, throughout the year. There are places, however, where the conditions are very close to those at Alexandria, and a large area, coinciding with the area of similar temperatures already referred to, extending from San Antonio, Tex., eastward through Montgomery, Ala., has a summer relative humidity similar to that at Alexandria and intermediate between the humidity at Alexandria and at Cairo. Ninety per cent of the cotton exported from Egypt is grown in the Delta, in a climate intermediate between that of Alexandria and Cairo, and therefore, as far as temperature and relative humidity are concerned, that portion of the United States which lies in a broad zone through central and northern Texas and central Louisiana, Mississippi, Alabama, and Georgia is the most promising territory for the growth of Egyptian cotton.

There is one point of importance regarding the climate of Egypt which is not brought out in the accompanying tables, and that is the great variability of the

relative humidity from day to day. There is hardly a month in the year in Egypt, especially in the upper part of the Delta, near Cairo, when the relative daily humidity has not a range of 70 per cent, or from a very dry to a saturated atmosphere. This great range is not characteristic of the cotton belt in the United States outlined above.

The table also shows the relative humidity at Yuma, Ariz., and a glance will show that the conditions there are totally different from the conditions existing in Lower Egypt.

The mean evaporation from a water surface in Cairo and from three places in the United States is shown in the following table. So far as can be found, there is no point in America where the evaporation during the summer months is the same as that in Egypt, but a glance at the table will show that the evaporation in Cairo lies intermediate between the figures for the cotton belt and those for Yuma, Ariz. The Weather Bureau statistics upon evaporation are very irregular and admittedly not altogether reliable, and it is thought that if observations were carried on with the same kind of instruments in the two countries places of greater similarity would be found.

*Comparison of mean evaporation from the water surface in Egypt and in the United States.*

Month.	Cairo, Egypt.	San Antonio, Tex.	Mont- gomery, Ala.	Yuma, Ariz.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
January.....	2.61			
February.....	3.14			
March.....	4.92			
April.....	5.77	4.68	4.81	8.32
May.....	7.18	5.27	4.24	9.17
June.....	8.23	4.79	5.83	10.56
July.....	8.51	6.77	3.65	9.87
August.....	7.17	6.54	4.27	9.08
September.....	5.21	4.71	4.12	9.73
October.....	4.25			
November.....	2.83			
December.....	2.43			
Year.....	62.25			

#### PHYSIOGRAPHY AND GEOLOGY.

The portion of the Colorado River Delta comprised in the Imperial country is almost unique in American agriculture, since it forms an area of over 1,000 square miles, the greater part of which lies below sea level. This region was once occupied by a northern extension of the Gulf of California, which had for its shore line the San Bernardino Mountains to the north and east and the Sierra Madre range, with its smaller spurs, to the west and south. Into this embayment the Colorado River poured a continuous sediment-laden stream of water derived from its more northern drainage basin. The gravel, sand, silt, and clay thus derived were built into an extensive submarine delta which gradually approached the surface of the water, and which was constantly pushed southward toward the Cocopah Mountains. Ultimately the northwestern arm of the Gulf of California became a mere

lagoon separated from tide water by the immense delta of the Colorado River, which now flowed across this delta bar well above sea level. Thus the first stage in the history of the Imperial country was that of an inland sea originally filled with salt water and later with brackish water. The marine and lagoon phases of the development of this section are abundantly proved by the existence of extensive beach-line deposits, especially well developed along the eastern and northern borders of the area. The constant association of marine fossils (*Venus*, species undetermined, and *Solen*, species undetermined) with the beach deposits proves their marine origin. Specimens of *Venus* were found not only along the marginal beaches, but also along the flanks of Superstition Mountain and upon a gravel bar about 4 miles northwest of Imperial.

After the Imperial basin became isolated from the Gulf of California it was subjected to rapid and continuous evaporation and also to frequent additions of fresh water through overflow of the Colorado River. It is therefore probable that the water of this lagoon fluctuated between salt and brackish water stages, depending upon excessive evaporation or the addition of fresh overflow water. Ultimately the lagoon was replaced by a dry basin extending to a depth of about 300 feet below sea level. Since that time repeated overflows from the Colorado have carried fresh water and suspended sediments into the area until the older marine deposits have been buried to varying depths. With these are associated great numbers of fresh-water shells of the species *Anodonta*, *Planorbis*, *Gnathodon*, *Physa*, and *Griobia*. Some of these inundations, especially those of earlier date, have been quite general over the area, depositing clay, silt, and fine sand in thin strata and shaly laminæ. In this manner the upturned strata found in Superstition Mountain have become partially buried and the buried portion of the range extends eastward across New River as an effective dam to subterranean waters slowly percolating northward. As a result strongly alkaline areas have been formed just to the south of Superstition Mountain and its buried extension, while a narrow belt to the north has been partially protected. Other inundations of smaller extent have added material over only a part of the area. Such deposits have occurred most frequently near the Mexican boundary line and for a few miles northward. Thus the surface materials from which the soils are derived are not continuous, but form thin, irregular lenses of sediment. This accounts for the noncontinuous character of the different sand layers and for the irregular depths at which sand was encountered in the borings taken during the mapping of the area. This noncontinuity of the sand layers prevents the natural underdrainage of the greater part of the territory and affects adversely the drainage reclamation of alkali tracts.

In addition to the salts contained in the original marine waters of

the basin, none of which have escaped, the recurring inundations from the Colorado have to a smaller extent carried alkali salts from the higher lands along sea level in the southern part of the area to lower portions of the basin. Thus in a general way the basin becomes more and more alkaline from the margin toward the lowest point of the Salton Sink. Seepage from the mesa along the eastern border of the area has also given rise to a long belt of alkali land east of the Salton River and to a few feeble springs.

Although the basin has been subjected to some general changes of level, as is shown by the upturning of the earliest sediments to form the Superstition Mountain range, the entire area has eventually returned nearly to its former position, as the proximity of the latest beach line to present tide level indicates.

The surface aspect of the Imperial country as formed under these conditions is that of a great plain sloping generally toward the northwest. It is bounded by a precipitous, rocky mountain rim to the north and west, by a fairly well marked mesa escarpment 20 to 60 feet high on the east, and by a low, gentle rise interrupted by sand dunes and the wandering channels of New and Salton rivers to the south. The southern margin is also broken by Signal Mountain, an isolated mass of crystalline rock which rises 1,400 feet above sea level. Superstition Mountain rises as a long, curved, serrated ridge in the west central portion of the area. Three or four small buttes occur in the Salton Sink south of Volcano Springs. Upon one of these is found a hot spring emitting fumes of sulphureted hydrogen.

The plainlike surface of the basin is only apparent, as the ground slopes from the old beach lines to a point nearly 300 feet below sea level at Salton Station on the Southern Pacific Railroad. The western border of the irrigable lands of the basin consists of groups and ranges of sand dunes piled up by the prevailing westerly winds. Many isolated groups of dunes are found within the basin, though none attain to the size of those occurring along the margin. These dunes are frequently crescent shaped, convex toward the direction of the wind, and have their maximum elevation at or near the center of the crescent arc.

The channels of the New and Salton rivers, which at the Mexican boundary line are several miles apart, converge farther north until they approach within a mile of each other. Near this point they change their course from a generally northerly direction, swinging to the northwest and soon spreading their waters out in the overflow region of the Salton basin. Both the Salton and New rivers are normally dry during the greater part of the year, but the latter is now maintaining a constant flow of surplus irrigation water. Near the Mexican boundary line the beds of both rivers are shallow, and flood waters tend to diverge and form new courses. Along New River this has given rise to several bayous like Laguna Lake, Blue Lake, Badger

Lake, and Pelican Lake. Mesquite Lake is similarly filled by overflows from Salton River. Near Imperial and several miles to the north both rivers have cut gorges from 20 to 40 feet deep. Adjoining these gorges the local surface drainage has cut deep arroyos during widely separated seasons of torrential rain. The arroyos are separated by flat-topped ridges of small area. This part of the country is frequently too rough for cultivation.

Within the limits of the sandier soil types of the basin the strong desert winds have excavated considerable material, forming deep scorings and extensive "blow-outs." The smaller scorings closely resemble large glacial striations, while the deeper "blow-outs" vary in depth from 2 feet to 6 feet or more. In some cases small pillars have been left standing, indicating the original surface before the wind erosion began. Areas of this character frequently cover many acres. A portion of the material thus removed has been piled up in regular sand dunes, while a part of it has been deposited in and around patches of desert shrubs and trees in conical or dome-like mounds. In some areas, strongly alkaline, the only vegetation existing is found on these mounds.

The chief factor in the formation of the Imperial basin has been sedimentation from the Colorado River, first under marine or lagoon conditions and later through frequent overflows into the dry basin. The chief agent now at work is the wind, which excavates, transports, and temporarily deposits a large quantity of material annually. The local rains are of such a character that the precipitation first collects on the almost level surface, and when a channel is once formed the flood water rapidly cuts deep, narrow washes to the nearby river courses. While a large amount of water is thus removed, a considerable proportion sinks into the surface soil.

Material which once enters the basin can only leave through wind transportation, and water flowing in can only escape by evaporation. Hence all soluble matter, whether valuable or deleterious, once entering the area must remain, making its way very slowly toward the lowest point in the basin, the Salton Sink.

#### SOILS.

In the survey of 1902 five types of soil were established for the Imperial area, and although nearly five times as great an area was covered during the present survey, but two new types—the Gila fine sandy loam and the Imperial gravelly loam—were found. This fact emphasizes the remarkable uniformity of the great body of sedimentary material forming the Colorado River Delta. The greater proportion of this material consists of fine particles of clay and silt, and the heavier classes of soils preponderate.

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The following table gives the actual and proportional area of each type of soil:

*Areas of different soils.*

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Imperial loam.....	341,056	49.2	Gila fine sandy loam.....	30,784	4.4
Imperial sandy loam.....	126,656	18.3	Imperial sand.....	1,792	.2
Dunesand .....	116,288	16.8	Total.....	693,696	.....
Imperial gravelly loam .....	43,328	6.2			
Imperial clay.....	33,792	4.9			

## IMPERIAL SAND.

The Imperial sand consists usually of 5 feet of fine to coarse sand, underlain by a loam or clay loam, which is in turn underlain by alternating strata of sand, sandy clay, loam, clay loam, or clay, extending to great depths. The sandy material is the same as that forming the Dunesand. There are in all 1,792 acres of this type, distributed through the southern half of the area in small, isolated bodies.

The soil is light, well drained, and practically free from alkali, except in the heavier subsoil, and with careful handling its condition with respect to alkali should grow better rather than worse. The chief concern will be the rise of the water table, which should be prevented by the moderate and judicious use of water. The texture and drainage of this soil make it the safest type in the area, and it is unfortunate that its extent is so limited.

The Imperial sand can be used advantageously for any of the cultivated crops and the fruits suited to the climate.

The following table gives the mechanical analyses of two samples of this soil:

*Mechanical analyses of Imperial sand.*

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
8063	SE. cor. sec. 36, T. 15 S., R. 16 E.	Sand, 0 to 12 inches.	0.05	0.00	18.04	21.90	34.10	24.10	0.16	1.66
8064	NE. cor. sec. 31, T. 15 S., R. 16 E.	Sand, 48 to 72 inches.	.05	.00	.10	.50	54.86	31.72	5.06	7.76

The following samples contained more than one-half per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 8063, 4 per cent; No. 8064, 5 per cent.

It will be seen from the foregoing table that the surface soil is a very pure sand, made up of the four different grades, the grade of fine

sand slightly preponderating. The soil contains less than 0.2 per cent of silt and only between 1 and 2 per cent of clay. With depth the texture becomes heavier, coarse and medium sand disappearing almost entirely and the proportion of fine sand increasing to over 54 per cent, silt to about 5 per cent, and clay to nearly 8 per cent. The percentage of organic matter in the soil is seen to be very small, and its fertility is due, therefore, to the mineral nutrients that have accumulated through the ages.

#### IMPERIAL SANDY LOAM.

The Imperial sandy loam to a depth of 3 feet is composed of the coarser sediment laid down by the Colorado River, mixed with some wind-blown sand. Beneath this surface covering is usually found a heavy sandy loam or loam, containing from over 12 to nearly 43 per cent of clay and from nearly 20 to over 58 per cent of silt. This subsoil, however, varies considerably and is sometimes a light sandy loam, or in the vicinity of Dunesand areas even a sand. In the field both the soil and subsoil appear of a lighter texture than is indicated by the laboratory analyses. This difference is due to the cementing of the fine particles by gypsum, which gives the soil a granular structure. In the course of analysis this granulation is broken down.

This type has the second largest extent of the soils of the area, occurring in large bodies of very irregular form reaching across the basin from southeast to northwest, in a general way following the course of the Salton River and of the New River in its northern part, immediately along which streams the largest two unbroken tracts of the type occur. Small, narrow bodies are situated at the foot of the Dunesand areas and Superstition Mountain on the western border of the survey.

There are, in all, 126,656 acres of Imperial sandy loam in the area. The greater part of this is covered with small hummocks composed of the surface soil, while some of the areas in the southern part of the map are very uneven and badly gullied:

There is a very wide range in the type as regards alkali conditions, as will be seen by consulting the maps. Some areas are comparatively free from alkali, while others are as badly affected as any soil in the area. The greater part of the type contains more than 0.20 per cent of alkali.

The Imperial sandy loam will take water well, and where level and free from alkali is adapted to a wide range of crops. The texture, however, becomes heavier with irrigation and not so well suited to the production of the intertillage crops requiring a porous soil, as to corn and sugar beets, for instance. However, with the organic matter added in cultivation the change due to the breaking down of the soil particles will be offset in some degree, so that except for the small

area of Imperial sand, this soil should remain the very best in the area for the intertillage crops, such, for example, as the fruits, including the date—if it can be successfully grown—vegetables, sugar beets, etc. The grain crops and alfalfa should also do well on this soil.

The following table gives the mechanical composition of this soil type:

*Mechanical analyses of Imperial sandy loam.*

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
8052	NW. cor. sec. 30, T. 15 S., R. 16 E.	Sandy loam, 0 to 72 inches.	P. ct. 0.26	P. ct. 0.00	P. ct. 0.08	P. ct. 0.30	P. ct. 21.04	P. ct. 42.92	P. ct. 21.78	P. ct. 13.80
8056	NE. cor. sec. 11, T. 17 S., R. 15 E.	Sandy loam, 0 to 24 inches.	.39	.00	.14	.20	10.46	42.96	32.00	14.62
8060	NE. cor. sec. 7, T. 16 S., R. 16 E.	Sandy loam, 0 to 24 inches.	.44	.00	.10	.10	2.24	15.84	55.92	25.80
8058	Cen. N. side sec. 32, T. 15 S., R. 16 E.	Sandy loam, 0 to 36 inches.	.22	.00	.10	.14	13.24	17.48	34.60	34.44
8057	Subsoil of 8056.....	Light loam, 24 to 72 inches.	.37	Tr.	.24	.10	3.70	28.88	54.12	12.54
8059	Subsoil of 8058.....	Sandy loam, 36 to 72 inches.	.20	.02	.06	.10	25.06	38.18	19.60	16.92
8062	Subsoil of 8060.....	Sandy loam, 48 to 60 inches.	.20	.00	.00	.04	1.50	9.56	58.76	30.16
8061	Subsoil of 8060.....	Loam, 24 to 48 inches.	.14	.00	.14	.30	1.10	10.04	45.88	42.64

The following samples contained more than one-half per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 8052, 8 per cent; No. 8058, 17.80 per cent; No. 8059, 15.60 per cent.

#### IMPERIAL LOAM.

The Imperial loam, after irrigation, is a sticky, reddish loam, a little heavier than a silt loam, having a depth of from 4 to 6 feet and resting on a clay or clay loam subsoil, which in turn is underlain by alternate strata of lighter and heavier material to an indeterminate depth. While the surface, which is usually as smooth and level as a floor, is almost devoid of vegetation, the soil itself often contains considerable organic matter and when irrigated is very productive.

The type owes its origin to the sediments brought down by the Colorado River and deposited in strata either while the area was still submerged or from the overflow waters as they spread over the plain. Before irrigation these strata, which vary from one-tenth inch to 2 or 3 inches in thickness, are quite hard and look like shale, although they soften readily when brought into contact with water, and a loamy soil results.

This soil is by far the most extensive type in the area. It stretches in one continuous body from about the middle of the eastern boundary entirely across the area in a northwestern direction and out into the

Salton Sink. It also forms a large proportion of the area lying west and southwest of Imperial, while large tracts lie in the southeastern corner of the area, between Mesquite Lake and the Mexican boundary line.

Some alkali is found in all this soil, and in many places it is greatly in excess of what even the most resistant plants can stand. It will be necessary to do much reclamation work before such tracts can be cultivated.

In texture the soil is well adapted to wheat, barley, sugar beets, Kafir corn, Egyptian corn, sorghum, and possibly many other crops that may be introduced from desert portions of the world that have a similar soil. Alfalfa, when not pastured, will do fairly well, but the tendency to pack makes difficult the extension of the tiny root-lets of this plant. Pasturing increases the tendency to pack and interferes with the movement of the irrigation water in the soil. There is no doubt as to the great productiveness of the soil; water is obtainable, and the surface is well suited to the practice of irrigation, so that in the portions now having less than the limit of tolerance of salts for crops suited to the region, or that can be freshened by ordinary flooding, large and profitable crops can now be grown. The removal of the alkali in the remainder of the area will make it as valuable as any of the type.

The following table shows the mechanical composition of the soil and subsoil of this type:

*Mechanical analyses of Imperial loam.*

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
8031	NE. cor. sec. 11, T. 17 S., R. 13 E.	Loam, 0 to 48 inches..	0.15	Tr.	0.40	0.38	2.70	6.14	36.94	53.44
8032	Subsoil of 8031 .....	Clay, 72 to 96 inches..	.03	0.00	.00	.20	.90	3.24	25.68	69.36

The following samples contained more than one-half per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 8031, 13 per cent; No. 8032, 12.20 per cent.

#### IMPERIAL CLAY.

The Imperial clay consists of the finest particles carried into the basin by the Colorado River. These form a very heavy clay, plastic and sticky when wet and hard and lumpy when dry. In its natural state this material is consolidated to such a degree that it breaks with

a rocklike fracture and is capable of taking a high polish. As might be inferred from this description, the soil will be very difficult to cultivate.

This type is found in two large and a few small bodies in the southern half of the area surveyed; but strata of the same material underly, at greater or less depth, all the other soil types, and because of their dense, impervious nature render the problem of reclaiming the alkali areas more than usually difficult.

The surface of this soil is for the most part even and well suited to irrigation, the exception being where the wind has raised low dunes, or hummocks, around slight obstructions.

All of this soil contains some alkali in the first 6 feet, and much of it sufficient to make its partial reclamation by flooding necessary before common crops can be grown.

Some crops of sorghum, millet, and barley have been produced on the better grades of this soil, and the yields have been very satisfactory. Sorghum, yielding from 6 to 8 tons to the acre, seems to do best. This is an alkali resistant plant. At first barley, which is also resistant to alkali, and later, after the surface soil has been somewhat sweetened, other small grains or crops not requiring intertillage are best suited to this soil, as the cost of tillage will be too great to permit the profitable production of the ordinary tilled crops. Egyptian cotton, which has been tried in a small way on this soil, does well, and if the climate proves suited to its production the culture of this crop should become a profitable industry. The type is also well suited to the growing of rice, of which it should produce large crops, provided climatic conditions are favorable. Its dense, close nature makes it undesirable for fruit trees. For alfalfa the soil is too dense, and it is doubtful if it would show any great degree of permanency even if a good stand should be secured. With proper handling and thorough reclamation this type will be more valuable than it is at present for the crops enumerated or for crops yet untried in the valley.

The table on the following page gives a number of mechanical analyses of the soil and subsoil of this type, by which the great preponderance of silt and clay in its composition is strikingly shown.

*Mechanical analyses of Imperial clay.*

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.06 mm.	Silt, 0.06 to 0.005 mm.	Clay, 0.005 to 0.001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
8043	$\frac{1}{4}$ mile N. cen. sec. 32, T. 11 S., R. 14 E.	Heavy loam, 0 to 12 inches.	0.77	0.00	0.04	0.12	0.28	3.24	73.08	23.24
8034	NE. cor. sec. 1, T. 15 S., R. 15 E.	Clay, 0 to 36 inches..	.80	.04	.08	.10	4.00	12.62	38.98	44.06
8042	N. cen. sec. 7, T. 12 S., R. 15 E.	Clay, 0 to 36 inches..	.45	.14	1.70	2.98	12.28	8.06	20.12	54.34
8038	NW. cor. sec. 18, T. 11 S., R. 14 E.	Clay, 0 to 36 inches..	.64	.00	.00	.10	1.00	2.30	41.40	55.18
8041	NE. No. 7-40 sec. 34, T. 11 S., R. 14 E.	Clay, 0 to 72 inches..	.94	.00	.10	.10	1.94	11.50	29.82	56.12
8040	E. side No. 3-40 sec. 33, T. 11 S., R. 14 E.	Clay, 0 to 60 inches..	.49	.00	.00	.08	.64	7.50	27.80	64.20
8035	Subsoil of 8034.....	Loam, 36 to 72 inches.	.27	.14	.26	3.32	48.02	27.48	8.36	12.38
8044	Subsoil of 8043.....	Heavy loam, 12 to 24 inches.	.67	.02	.12	.14	.18	1.04	60.52	37.96
8046	Subsoil of 8043.....	Clay, 36 to 48 inches.	.62	.00	.08	.08	.14	1.80	52.96	44.72
8047	Subsoil of 8043.....	Clay, 48 to 60 inches.	.54	.00	.00	.00	.10	5.18	44.26	50.02
8045	Subsoil of 8043.....	Clay, 24 to 36 inches.	.65	.00	.02	.04	.08	.80	48.06	51.00
8048	Subsoil of 8043.....	Clay, 60 to 72 inches.	.41	.00	.00	.00	.26	4.48	43.36	51.26
8039	Subsoil of 8038.....	Clay, 36 to 72 inches.	.60	.00	.00	.10	.40	1.28	10.90	86.40

The following samples contained more than one-half per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 8043, 35 per cent; No. 8034, 21.40 per cent; No. 8042, 13.60 per cent; No. 8038, 42.40 per cent; No. 8041, 16.80 per cent; No. 8040, 22.20 per cent; No. 8035, 12 per cent; No. 8044, 46.40 per cent; No. 8046, 38.80 per cent; No. 8047, 32 per cent; No. 8045, 29.40 per cent; No. 8048, 16.60 per cent; No. 8039, 34.80 per cent.

## IMPERIAL GRAVELLY LOAM.

The Imperial gravelly loam is found along the old beach lines on the eastern and northern boundaries of the basin and around the base of Superstition Mountain. It ranges from the old beach level to an extreme depression of about 125 feet below tide. This extension of the gravel is chiefly due to wave action during the marine or lagoon stages of the basin, but along its northeastern side long, flat alluvial fans have been spread out on the floor of the sink. This latter spreading has been brought about by many torrents descending from the mountains. The gravel consists of agate, quartz, chert, flint, limestone, granite, obsidian, and indurated clays, varying in size from a fraction of an inch to 5 or 6 inches in diameter. Along the old beach lines and also among the alluvial cones there are found many fragments of ferruginous hardpan, some of which amount to local ledges, while others are mere pipes or pebbles. The gravel and sandstone are mixed with sand near the old beach lines, or indiscriminately with

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loam, clay, or sand where the gravel zone has been extended out upon the floor of the basin.

Near the old beach level and in the sandy phases there is little alkali in the surface 6 feet of this material. In the loam phases, especially north of the Southern Pacific Railroad, the gravel and loam mixture frequently contains more than 1 per cent of alkali. Much of the gravelly loam is too rough for economical leveling for irrigation, and some along the northern boundary of the area is subject to destructive erosion by flood waters from the mountains. All areas, however, that can be irrigated from the valley and that can be economically leveled will prove to be valuable for fruits suited to the climate.

The following table shows the results of mechanical analyses of fine earth samples of the Imperial gravelly loam:

*Mechanical analyses of Imperial gravelly loam.*

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
8049	2 miles NE. of Volcano.	Gravelly loam, 0 to 24 inches.	0.15	2.44	8.48	11.78	39.36	13.40	7.08	16.46
8050	Subsoil of 8049....	Clay, 24 to 72 inches.	.08	.80	2.84	3.40	12.20	4.66	25.00	50.56

The following samples contained more than one-half per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 8049, 5.60 per cent; No. 8050, 13.40 per cent.

GILA FINE SANDY LOAM.

The Gila fine sandy loam is a mixture of medium to fine sand having the properties of a sandy loam. Like all the other soils of the valley, it is of a reddish-brown color. It is from 3 to 6 feet deep or more and is usually underlain by a light loam or sandy loam, which is in turn underlain by alternating strata of loam, clay loam, clay, or sand to undetermined depth. It is found principally along New River, in the vicinity of Blue Lake, but other areas are found farther north on New River, and there is one important area northeast of Mesquite Lake.

The surface is usually level or only slightly scored by wind. Little labor is necessary to prepare it for irrigation. As this soil usually occurs along the river, it is well drained and is likely to remain so. Only a very little of it contains alkali in harmful quantities.

A few crops have been grown on this soil near Blue Lake, with good results. It is well adapted to all of the field crops and fruits suitable to the climate of the valley. A higher percentage of this soil than any other is free from alkali, and since it is easily cultivated and

is very fertile it bids fair to become the most valuable type in the valley.

The following table shows the mechanical composition of this soil type:

*Mechanical analysis of Gila fine sandy loam.*

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
8030	NE. cor. sec. 15, T. 16 S., R. 12 E.	Fine sandy loam, 0 to 60 inches.	P. ct. 0.43	P. ct. 0.00	P. ct. 0.08	P. ct. 0.42	P. ct. 1.40	P. ct. 34.72	P. ct. 48.96	P. ct. 14.36

The following sample contained more than one-half per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 8030, 13.20 per cent.

#### DUNESAND.

The Dunesand of the Imperial area consists of a medium to very fine yellow or reddish-yellow sand, with which are mixed flakes and concretions of loam. The depth of this material was rarely determined, as deep borings were impossible. As the dunes usually occupy areas in the sandy type of soil it may be fairly estimated that the same material extends to the average depth of this soil below the floor of the valley. The dunes, which vary in height from 2 or 3 feet to 30 or 40 feet, rest upon the loam or clay soils of the delta and are being slowly propelled across its surface by the prevailing westerly winds. The forward progress of the individual dunes is accomplished in two ways. The coarser sand is rolled along the surface or lifted to a slight elevation for short distances. When an obstruction is encountered a small deposit is made on its lee side, and additional material is carried over the top and around the sides or ends. In this way a central pile is formed, having low crescent-shaped wings, which swing forward from the main mass in the direction toward which the prevailing winds blow. A single storm may modify this form or create a secondary crescent on the leeward tip of the old dune.

The great expense of leveling these dunes for irrigation makes them undesirable for agricultural purposes at present, although they are normally free from harmful amounts of alkali and are of a texture favoring cultivation.

#### WATER SUPPLY FOR IRRIGATION.

The water for irrigation in the Imperial area is diverted from the Colorado River,  $7\frac{1}{2}$  miles below Yuma, Ariz. From this point it is carried through a canal 8 miles long into the Salton River channel,

which is used as a canal for a distance of 60 miles through Mexican territory. A canal, with a capacity of 5,000 second-feet, is taken out of the Salton, a short distance south of the international boundary line, for the distribution of water in the United States. This canal will cover lands lying between the Salton River and the New River, and on the west side of the New River, north of Superstition Mountain. Other canals are planned to leave the Salton at different points to irrigate lands in Mexico and in the United States east of Salton River and west of New River near the Mexican boundary line.

The quality of the water is very good, and it may be freely used, so far as danger from injurious salts in solution is concerned. The total soluble matter averages less than 100 parts in 100,000, and there is in the water, as taken from the Colorado, a great deal of matter in suspension that is of considerable value as fertilizer. A part of this sediment is deposited in the channel of the Salton, but as delivered in the area surveyed the water still contains much valuable plant food, both in solution and in suspension.

The amount of water available for irrigation is more than sufficient to supply present demands, and probably enough to supply the needs of the country indefinitely.

The canal system is being constructed by the California Development Company, which owns lands both in Mexico and the United States, and is incorporated under the laws of both countries. The actual distribution of the water and the maintenance of the minor canals are delegated to mutual companies composed of owners of the land who have purchased water stock of the parent company. Water stock was first sold under a plan of rebate at a net price of \$5.75 per share. By January, 1902, the stock had been advanced to \$20, but later it was reduced to \$15, and this was the ruling price in January, 1903.

The mutual companies pay only 50 cents per acre-foot for water, but in addition to this there is an indefinite assessment which the farmers are compelled to pay toward the maintenance and repair of the canals and canal works.

#### ALKALI IN SOILS.

On a basis of the soil taken to a depth of 6 feet there is alkali throughout the area mapped. Sometimes this is in the deeper subsoil, and sometimes in the surface foot or two. The intensity of the accumulation varies greatly from place to place. Often the proportion is great enough to preclude the growing of crops unless the land is first reclaimed.

All the land of the area has been arranged into six classes each of which is shown by distinct color and symbol on the alkali map

accompanying this report. The following table gives the area and proportional extent of the several classes:

*Areas of different grades of alkali soil.*

Grade of soil.	Acres.	Per cent.
From 0 to 0.20 per cent.....	186,240	28.6
From 0.20 to 0.40 per cent.....	110,016	16.9
From 0.40 to 0.60 per cent.....	91,008	13.9
From 0.60 to 1 per cent.....	73,600	11.4
From 1 to 3 per cent.....	120,448	18.6
Over 3 per cent.....	69,376	10.6

These different grades are roughly gauged by their crop utility as follows: The first will grow all but the most sensitive crops; the second can be used for all the common crops, while it gives almost as good yields of alfalfa, corn, barley, melons, peaches, figs, grapes, and berries as alkali-free soils; the third grade will just produce alfalfa when the field is once well established; the fourth grade can be used only for growing the most resistant crops, such as sugar beets, sorghum, or date palms; the fifth will grow no crop less resistant than the date palm, while the sixth is the maximum allowing of plant growth.

The map, as stated, is constructed on a basis of the mean salt content of the surface 6 feet of soil. The availability for crops depends not only on this mean, but also on the position of the salt in this 6-foot section, and whether it is evenly or irregularly distributed. Deep-rooted plants, as for instance fruit trees, may thrive in the early stages of their growth, only to die when their roots come in contact with accumulations in the deeper soil, while the shallow-rooted crops may yield well on land with little alkali in the surface foot or two, although at a greater depth the soil may be heavily impregnated.

It should be remembered, however, that when there is a considerable quantity of alkali in the 6-foot zone there is always a chance that it will accumulate at the surface, especially if irrigation be careless or excessive, and therefore the true condition or value of any given area can best be judged by the mean salt content as given.

Alkali under favorable conditions can rise from even greater depths than 6 feet, and as the deeper subsoil in the Imperial area was known to be heavily impregnated, a number of deep borings were made with a view to a better understanding of the true conditions. The table following shows the results of these borings.

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*Results of deep borings.*

[Per cent alkali in each foot of soil.]

Depth in feet.	Boring 178. NE. cor. sec. 11, T. 17 S., R. 13 E.		Boring 192. NE. cor. sec. 23, T. 16 S., R. 12 E.		Boring 216. Center N. side sec. 30, T. 15 S., R. 13 E.		NW. cor. sec. 30, T. 15 S., R. 16 E.		Boring 434. NE. cor. sec. 2, T. 13 S., R. 15 E.		Boring 238. NE. sec. 21, T. 13 S., R. 13 E.		Boring 426. E. center sec. 27, T. 12 S., R. 14 E.		1½ miles SE. of Mesquite Lake.	
	Tex- ture.	Per cent.	Tex- ture.	Per cent.	Tex- ture.	Per cent.	Tex- ture.	Per cent.	Tex- ture.	Per cent.	Tex- ture.	Per cent.	Tex- ture.	Per cent.	Tex- ture.	Per cent.
0 to 1	sc	0.85	ssc	0.22	sc	0.63	ssc	1.26	sc	0.21	sc	1.48	sc	0.60	ssc	0.26
1 to 2	sc	1.50	c	.83	ssc	.34	ssc	.76	sc	.43	sc	1.10	sc	1.00	ssc	.64
2 to 3	sc	.65	c	1.03	s	.22	ssc	1.00	sc	.35	sc	.85	sc	.72	ssc	.57
3 to 4	sc	.50	c	1.46	s	.15	ssc	.92	sc	.30	ssc	.69	sc	.43	ssc	.53
4 to 5	ssc	.44	c	1.45	s	.18	ssc	.69	sc	.25	c	.68	sc	.41	ssc	.63
5 to 6	c	.46	c	1.34	s	.09	ssc	.89	sc	.28	c	.90	sc	.45	ssc	.60
6 to 7	c	.49	sc	1.08	c	.57	ssc	1.20	sc	.31	c	.59	ssc	.50	.....	.....
7 to 8	c	.48	c	.....	ssc		ssc	1.05	ssc	.25	c	.61	ssc	.49	fsl	.77
8 to 9	c	.38	c	1.06	ssc	.53	sc	1.60	ssc	.28	sc		ssc	.49	fs	.40
9 to 10	.....	.....	c	.....	ssc		c	1.90	ssc	.30	sc	.45	c	.55	ssc	1.22
10 to 11	.....	.....	c	1.15	c	.49	c		.....	.....	.....	.....	sc	.45	.....	.....
11 to 12	.....	.....	c	.....	c		c	1.64	.....	.....	.....	.....	sc	.45	.....	.....
12 to 13	.....	.....	c	1.28	c	.49	c		.....	.....	.....	.....	.....	.....	.....	.....
13 to 14	.....	.....	c	.....	ssc		c	.....	.....	.....	.....	.....	.....	.....	.....	.....
14 to 15	.....	.....	sc	1.30	ssc		c		.....	.....	.....	.....	.....	.....	.....	.....

NOTE.—C = clay; ssc = clay loam; ssc = sandy loam; sc = loam; s = sand; fs = fine sand; and fsl = fine sandy loam.

The greatest extent of badly alkaline land is found in the extreme northwestern part of the area. Here all of the soil contains more than 1 per cent, and is of no present value agriculturally. Superstition Mountain cuts off the subdrainage, bringing the water to the surface on the south side, where there is another large area very strongly alkaline, although here there are patches containing less than 1 per cent. This area of alkali land extends in a northeasterly direction to Mesquite Lake, and includes the town of Imperial. Just below the beach line which borders the area on the east there is another belt of very alkaline land which extends as an almost continuous area from Old Beach to the north side of T. 16 S. The salt here has come from the evaporation of sea water along the old salt beach, which, in the subsequent filling of the basin with fresh water, was not covered.

The alkali of the Imperial country is all white alkali, principally the chlorides of potassium and sodium. Lime is present both as sulphate and carbonate. If the soils are kept well drained there is enough gypsum in the soil and water to preclude all possibility of there ever being an accumulation of black alkali. As the area is now below sea level and the soils were most likely deposited in salt or brackish water when this was a part of the sea, we may directly conclude that the major part of the alkali came from sea water. The floods from the Colorado have brought in other salts, particularly

sulphates, and much changed the composition of the salts deposited from the sea.

The following table shows the results of an analysis of a mixture of 8 samples of alkali crust collected from various parts of the desert:

Constituent.	Per cent.	Constituent.	Per cent.
Calcium sulphate ( $\text{CaSO}_4$ ) .....	9.91	Sodium bicarbonate ( $\text{NaHCO}_3$ ) .....	9.59
Magnesium sulphate ( $\text{MgSO}_4$ ) .....	9.02	Sodium nitrate ( $\text{NaNO}_3$ ) .....	8.91
Sodium sulphate ( $\text{Na}_2\text{SO}_4$ ) .....	.33	Sodium chloride ( $\text{NaCl}$ ) .....	32.22
Potassium chloride ( $\text{KCl}$ ) .....	30.02		

The following table gives the results of chemical analyses of a number of samples of soils from the desert:

*Chemical analyses of alkali soils and subsoils.*

Constituent.	8030 NE. cor. sec. 15, T. 16 S., R. 12 E.	8031 NE. cor. sec. 11, T. 17 S., R. 13 E.	8032 Subsoil of 8031.	8033 E. side 3-40 sec. 33, T. 11 S., R. 14 E.	8034 NE. cor. sec. 1, T. 15 S., R. 15 E.	8035 Subsoil of 8034.	8036 One-fourth mile W. of Volcano.	8037 Subsoil of 8036.	8038 NW. cor. sec. 18, T. 11 S., R. 14 E.	8039 Subsoil of 8038.
Ions:	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
Calcium (Ca) .....	11.26	15.63	12.57	2.21	7.05	6.61	7.83	9.09	6.91	3.11
Magnesium (Mg) .....	3.15	2.91	1.92	1.10	2.86	3.23	2.30	3.66	2.02	2.74
Sodium (Na) .....	11.71	11.88	17.18	27.15	26.08	23.82	24.82	20.21	24.77	26.58
Potassium (K) .....	4.96	2.29	3.27	1.93	.36	1.32	.87	1.00	1.70	1.59
Sulphuric acid ( $\text{SO}_4$ ) .....	31.54	24.59	26.24	32.14	7.60	14.27	15.67	24.17	23.20	32.16
Chlorine (Cl) .....	15.77	32.70	36.72	15.52	55.27	45.46	47.39	39.92	39.79	29.84
Bicarbonic acid ( $\text{HCO}_3$ ) .....	21.61	10.00	2.10	19.95	.78	5.29	1.12	1.95	1.61	3.98
Conventional combinations:										
Calcium sulphate ( $\text{CaSO}_4$ ) .....	38.32	34.78	37.17	7.48	10.75	20.15	22.21	30.91	23.47	10.54
Calcium chloride ( $\text{CaCl}_2$ ) .....		15.00	4.50		10.80	1.91	3.62			
Magnesium sulphate ( $\text{MgSO}_4$ ) .....	5.85			5.26				2.95	8.30	18.64
Magnesium chloride ( $\text{MgCl}_2$ ) .....	7.20	11.47	7.54		11.21	12.65	9.04	11.99	1.39	
Sodium sulphate ( $\text{Na}_2\text{SO}_4$ ) .....				33.51						20.46
Sodium chloride ( $\text{NaCl}$ ) .....	9.45	20.39	41.68	22.72	65.48	55.59	61.95	49.60	61.41	46.86
Potassium chloride ( $\text{KCl}$ ) .....	9.45	4.61	6.25	3.60	.70	2.50	1.65	1.89	3.23	3.01
Sodium bicarbonate ( $\text{NaHCO}_3$ ) .....	29.73	13.75	2.86	27.43	1.06	7.20	1.53	2.66	2.20	5.49
Per cent soluble .....	.45	.96	3.42	.72	7.69	1.16	6.41	3.38	4.46	2.26

*Chemical analyses of alkali soils and subsoils—Continued.*

Constituent.	8040 E. side 3-40 sec. 35, T. 11 S., R. 14 E.	8041 NE. 1-40, sec. 34, T. 11 S., R. 14 E.	8042 N. C. sec. 7, T. 12 S., R. 15 E.	8043 One-fourth mile N. C. sec. 32, T. 11 S., R. 14 E.	8044 Subsoil of 8043.	8046 Subsoil of 8043.	8048 Subsoil of 8043.	8049 2 miles N.E. of Vol- cano.	8050 Subsoil of 8049.	8052 NW. cor. sec. 30, T. 15 S., R. 16 E.
Ions:	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
Calcium (Ca) .....	3.26	5.79	4.34	5.98	6.90	5.55	4.93	4.53	3.98	15.15
Magnesium (Mg) .....	2.74	1.95	.98	.93	.63	.71	1.05	1.94	2.10	6.06
Sodium (Na) .....	26.66	24.69	23.89	24.30	24.44	24.91	25.75	26.86	25.06	7.06
Potassium (K) .....	2.07	1.73	3.94	3.28	2.86	3.58	1.41	1.62	2.57	2.35
Sulphuric acid (SO <sub>4</sub> ) .....	27.25	33.82	45.76	37.46	33.12	31.58	40.94	20.87	16.15	20.24
Chlorine (Cl) .....	34.46	28.55	11.63	23.13	26.96	25.07	17.46	36.41	30.47	32.99
Bicarbonic acid (HCO <sub>3</sub> ) .....	3.56	3.47	9.46	4.92	5.09	8.60	8.46	7.77	19.67	16.15
Conventional combinations:										
Calcium sulphate (CaSO <sub>4</sub> ) .....	11.06	19.70	15.38	20.31	23.46	18.82	16.75	15.37	13.36	28.67
Calcium chloride (CaCl <sub>2</sub> ) .....										18.52
Magnesium sulphate (MgSO <sub>4</sub> ) .....	13.58	9.70	4.73	4.57	3.18	3.40	5.11	9.38	8.43	
Magnesium chloride (MgCl <sub>2</sub> ) .....									1.87	23.53
Sodium sulphate (Na <sub>2</sub> SO <sub>4</sub> ) .....	12.76	18.03	46.17	28.76	20.69	23.12	37.07	3.89		
Sodium chloride (NaCl) .....	58.78	44.47	13.21	33.34	40.15	36.02	26.80	57.60	44.03	2.69
Potassium chloride (KCl) .....	3.93	3.33	7.49	6.22	5.52	6.82	2.64	3.08	4.91	4.37
Sodium bicarbonate (NaHCO <sub>3</sub> ) .....	4.89	4.77	13.02	6.80	7.00	11.82	11.63	10.68	27.40	22.22
Per cent soluble .....	2.70	2.76	1.01	1.70	1.88	1.12	1.13	1.24	.85	.60

## HARDPAN.

In any irrigated country, when the ground water is not reached by percolating rain water, none of the soluble matter is leached entirely out, but is carried into the subsoil only to the maximum penetration of this rain water. A part of the salt thus carried down is, in the dry season which follows a rain, returned to the surface by the capillary rise of the water as it is evaporated. There is, however, a slight deposition during each rainfall at the point of contact between the dry and moist soil. In time there will come to be more salt at this point—the maximum penetration of rainfall—than there is at any other in the zone affected by rain water. In some regions this results in a closely cemented hardpan, which offers an impenetrable barrier to plant roots and is of itself a serious menace to any deep-rooted crop; although in most instances the only accumulation is of the easily soluble salts, usually referred to as “alkali.”

This latter is the case in the Imperial country, where there is no hardpan, but merely an accumulation of salts. A greater amount of salt is often found in the second foot than there is in the first. This accumulation is usually at about 18 inches, which for all except the very sandy soils may be taken as the maximum penetration of the very light rainfall. This penetration is comparatively so slight that

it has not materially affected the alkali condition of the country. The fact that a part of the surface foot has been washed into the second will make the production of one or two crops possible on land that otherwise would not produce at all, but the real alkali condition is not bettered permanently.

#### UNDERGROUND WATER.

A well bored at Imperial to more than 600 feet found the same sedimentary deposits as occur nearer the surface. Nearly the whole of the vast bed of alluvium was deposited in sea water, which normally contains more than 3 per cent of salt, and this salt has remained in the basin. None has leached out, for there is no possible place for it to go. Evaporation is the only means by which water escapes. As the basin has from time to time partially filled with fresh water from the river, a part of the salt of the surface few feet has been leached into the sub-soil and possibly a part has been carried to the lower parts of the sink, where this accumulation has been added to the salt from the last evaporating water of the lake. This makes a moist alkali flat of nearly all the area between Old Beach and Mortmere, on the Southern Pacific Railroad, an area 34 miles long by about 15 miles wide, or 510 square miles.

There is now a small lake at the bottom of the Salton Sink, and much of the surrounding country is wet and boggy. From this part of the sink back to the highest point, along the Mexican boundary, the depth of the water table has been determined at but few points. At Calexico, the deepest point yet found, it is 48 feet to water in an open well dug by the California Development Company. The deep well at Imperial, already mentioned, was bored for the company by Mr. Tingman, of Indio. Mr. Tingman is authority for the statement that here water was encountered at 23 feet. One-half mile south of Imperial the writer has found soil almost saturated at 15 feet. Southwest of Imperial, about halfway between Imperial and Blue Lake, on sec. 30, T. 15 S., R. 13 E., a 15-foot boring was made, in the bottom of which the soil was almost saturated. Other wells reported by the residents to have been dug in the vicinity of Imperial show the water to be between 20 and 25 feet from the surface. Farther north, on the north side of Superstition Mountain and between the two rivers, near Braley, the water table is again lowered to possibly 40 feet, from which point it gradually nears the surface as the bottom of the sink is approached.

The well water is in all cases salty. The water from the well at Calexico has never been used. Water had to be hauled for the teams and men when the deep well at Imperial was dug, for the water encountered was so salty it could not be used. A very few shallow wells in the beds of Salton and New rivers afford fair water, but the

great bed of ground water which extends everywhere throughout the sink is salty. Every deep boring made in the country shows the sub-soil to contain alkali in quantity, and a test made of soil taken from Superstition Mountain, which must have originally been several hundred feet below the surface and which since being elevated has been subjected to the washing of the rain for ages, showed 1.33 per cent salt.

All the evidence at hand goes to show that all of the alluvial material of the valley below the ground water is alkaline, and very badly so; that in the most strongly impregnated places in the valley the alkali is not merely a surface accumulation, but extends many feet in depth; and that the alkali comes almost wholly from the evaporation of sea water and river water, and not from degradation of soil in place or from the weathering of sedimentary rocks, as is often the case in other arid regions.

Since the accumulation of the alkali is due to the evaporation of the water which once occupied the sink, and since water of the same character is now dangerously near the surface in some places and may become so in all places, it is easy to see that the alkali question is of the gravest importance. All cultivation and irrigation should have other definite objects in view than the nourishing of present crops. These objects should be the partial reclamation of the surface soil that is now strongly alkaline, so that crops can be grown to pay the expense of ultimate reclamation, and the prevention of the rise of the water table and further injury to lands that will now produce fair crops. The greatest danger lies in the rise of the water table, and this danger seems to be the least recognized. The very thing that will tend to better the condition of the immediate surface for a time—copious surface flooding—will also tend to fill the soil with water and raise the water table. Precautions to keep this water down should be taken as soon as there is the least evidence of its rising.

The methods of reclaiming similar soils on a very extensive scale have been fully discussed by Means, in Bulletin No. 21 of this Bureau, which should be consulted.

In brief, the facts are as follows: The soils of Egypt consist of fine sands, sandy loams, loams, silt loams, clay loams, and clays, grading gradually from one to another, with no sharp boundaries. Of these, the clay loams and clays occupy by far the greater area. These soils are black, sticky, and plastic, and resemble adobe, having the same tendency to bake, clod, and crack. The silt loams are considered the soils best adapted to general farming, while the sandy soils are not considered so valuable as the other types, lying higher, being apt to suffer from drought, and having relatively little organic matter in their composition.

Reclamation is being carried on in many places in Egypt. A typical work is that at Abukir. There a stock company is reclaiming a large tract of land, a part of an old lake bottom, where the soil contains an average of more than 8 per cent of soluble salt in the first 3 feet, the greater part of which is sodium chloride, although a part is calcium sulphate, or gypsum, which is but slightly soluble in water and is more beneficial than harmful in the soil. The soil of the Abukir Lake bottom is typically a heavy, dense, sticky, black clay, apparently very impervious to water and difficult to underdrain. In fact, the whole aspect of the land is one of utter hopelessness, and none but the most sanguine of engineers would have undertaken its reclamation. There is, however, some lighter, though less fertile, soil in the lake bottom, and nearly all the land is underlain by sand at a greater or less depth.

The first step in the reclamation is the construction of canals and drains. The drainage water is run by siphon into an adjoining salt lake, from which it is pumped into the Mediterranean. There are main and secondary canals, and main, secondary, and tertiary drains, the distance between the latter being 164 feet. The land is so nearly level that very little fall can be given the canals and ditches. The main drains and canals have a fall of 1 in 20,000, or  $3\frac{1}{8}$  inches to the mile, while the laterals and sublaterals are almost level.

The cost of this canalization is about \$12.50 an acre. This includes not only the cost of construction of canals and ditches, but also expenditures for pumping plant and the general expenses of the company, such as buildings, machinery, superintendence, etc.

The actual process of reclamation begins with a thorough leveling of the land, which has been divided by the drainage ditches into small fields, termed "gatas." When leveled the water is turned into each gata to a depth of 4 inches, which depth is maintained if possible until the land is sufficiently sweetened to grow a crop. During this period the salt is dissolved and carried away in the drainage water. The water becomes very salty, often containing as high as 10 per cent of sodium chloride. One season's washing sweetens some of the land enough to allow crop growth, but as a rule it takes two seasons, in which case the land is plowed during the summer, when water is scarce, in order to prevent the accumulation of salt through evaporation. At the end of the second year the land is in most cases ready for the first crop. This is barnyard grass (*Panicum crus-galli*), called by the natives "dineba." If the catch of dineba is good, it is followed by Egyptian clover, and if this does satisfactorily cotton may be planted. Rice is also a reclamation crop.

If at any step in the process the crop planted does not indicate the proper state of advance in the work of reclamation, the gata is again flooded and the preceding crop in the rotation is again planted. The

total cost of reclamation in the Abukir tract, which may be taken as typical of the salt lands of Egypt, is given as \$18.30 an acre. Thirty dollars an acre is the cost, including the original purchase price of the land.

#### PRESENT AND PROSPECTIVE DEVELOPMENT.

Water was first brought to the area in June, 1901, in a small ditch along the route of the proposed larger one. This water was used for domestic purposes, watering stock, and for irrigating a small extent of land. The part of the main canal to the point where the 30-foot canals commence is finished. From this point one of the 30-foot canals is for the most part finished to Braley, and many of the laterals, with check gates and headings, are constructed. The permanent heading at Salton River, 7 miles southeast of Calexico, consisting of combined heading and 8-foot drop, has been built. A dam southeast of Imperial, in the Salton River, furnishes a diverting point for the eastside lands, and another directly east of Imperial forms a heading for a small system which is to irrigate lands south and east of Mesquite Lake. Work on a flume across New River and on a canal to irrigate lands west of the river has begun, while a part of the ditch system for the lands near the Mexican boundary line, and west of New River, has been constructed. The permanent headgate at the point 7 miles below Yuma has been located, and the work of construction is promised soon to begin there.

About 165,000 acres of Government land had been filed upon up to January, 1903. In the season of 1902 quite a large acreage of barley, sorghum, and Egyptian and Kafir corn was grown under Water Company No. 1, which irrigates land between Salton and New rivers. These crops furnished enough hay and grain for the work stock of almost the entire valley for the following winter, and besides fattened several hundred head of hogs and cattle. That part of the country not too badly alkaline produced in abundance the crops sown. West and a short distance south of Imperial a fair crop of barley was obtained on badly alkaline lands, the alkali from the immediate surface being washed below the surface foot by copious flooding. In the immediate vicinity of the town, however, the crops were practically a failure.

Calexico remains but a company headquarters, there being but one store besides the company's building. At Barnes,  $1\frac{1}{2}$  miles east of Calexico, there is a post-office and store. Imperial has grown to be quite a thriving village, and in February, 1903, contained possibly 300 people. There were at that time in the town 5 general merchandise stores, a drug store, a blacksmith shop, 2 hotels, 2 restaurants, 2 corals doing a livery business, 2 watchmakers' shops, 2 butcher shops, and a lumber and commercial company. At this point is published the Imperial Press. The Southern Pacific Railroad Company has

built a branch line from Old Beach to Imperial, which brings the country in much closer touch with the outside world, and will greatly aid in marketing the products of the country.

The sole dependence of the people of the Imperial area must always be agriculture. Mining will be limited to getting out the surface salt deposits in the bottom of the Salton Sink. There is nothing to attract the tourist, as in other parts of southern California. The source of wealth, therefore, is limited to the soil, and to a greater extent than in almost any other part of the country. Thus the problem confronting at least a part of the farmers in most arid regions is here—where alkali is so generally distributed in the soils and the conditions so unfavorable to reclamation—about as serious as it could well be.

In many regions where lands originally good have become alkaline the injury has resulted from the ignorance or carelessness of the agriculturists. A thorough knowledge of soil conditions at the beginning of cultivation, a careful, rational application of water in irrigation, and a system of cultivation and rotation of crops tending to benefit the land permanently would have been possible in most of these cases, and the harmful accumulations could have been wholly or partially prevented. But the danger has not been seen, or at least not admitted, until a part of the land has been so badly affected as to produce no crops. It is always easier to prevent the injury of lands than it is to reclaim them after they have become alkaline, and as long as partial crops can be grown some returns can be had from the land itself for the money expended.

The people of the Imperial country should recognize the fact that aside from the general problem of securing water for irrigation they have to solve perhaps the most serious agricultural problem of the arid west. Here is found a most refractory soil, much of it highly impregnated with alkali. The only way to benefit the land is to carry away the salts. The application of gypsum can not be of the slightest benefit. Little or no benefit will be derived from running water across the land with the expectation of flushing the alkali off the surface. The first water run onto the land may dissolve the surface salt and sink it into the soil a little way, but repeated tests made in this way have shown that the water as it comes off the lower end of the field contains no appreciably greater proportion of salt than when it was taken from the ditch above. The water must pass through the soil and find ready egress through natural or artificial drainage ways.

The quantity of salt taken out of the soil by alkali-resistant crops, such as sorghum and sugar beets, is not appreciable, the benefit to the soil in such cases resulting mainly from the prevention of evaporation at the surface through cultivation and from the leaching of the salts into the subsoil by the irrigation water. If the subsoil be practically

free from salt, as is often the case in arid regions, this vertical distribution of the salts alone is often all that is necessary so to reclaim the soil that sensitive crops can be grown. But it has been shown that in the Colorado desert the subsoil is the greatest source of danger, so that every bit of salt removed should be permanently removed. Whether this can be done depends wholly upon the drainage. The rapidity with which water leaches through and drains away from a soil is dependent upon the texture of the soil and subsoil. A loose, friable, sandy loam or sand takes and gives up water very readily, so that such a soil should be easily washed free from salts if there be an outlet for the drainage water. On the other hand, a sticky clay or loam takes water slowly and drainage in such soils is poor. By far the greater extent of the soil of the valley is a sticky, plastic loam or clay, through which water passes very slowly. The natural drainage in the soil itself is very poor, and to be anything like adequate it must be supplemented by artificial drains to carry off the ground water as the salts are washed down from the surface. The channels of New and Salton rivers furnish good natural outlets for these drains. If the heavier soils be drained, and care be exercised in the handling of the lighter ones, little damage will be done to the latter. Tile drains are the best and in the end the most economical for draining the land. They are, however, expensive, and the question is, will it pay?

Thoroughly to tile-drain the heavier soils will cost at least \$25 an acre, and the work can be properly done only in a large way and through the cooperation of all the farmers in maintaining the main drains, etc. For the very worst alkali lands this will have to be done before any paying crops can be grown at all, and it is only a matter of time until it will have to be done on some of the other soils that will now produce fair crops. This cost, added to the cost for water stock, makes an initial expenditure of about \$40 an acre.

That it will eventually pay to drain these lands there can be little doubt, but in the present state of the country concerted action will be difficult and individual effort futile.

Many of the present landowners have expended all their capital for first payment of water stock and for farm equipment, expecting to obtain sufficient revenue from crops to meet future payments and to improve their farms, and for these the expenditure of the sum necessary to reclaim the badly alkaline lands is out of the question. They can not wait for the lands to be reclaimed, and unless their first crops are a success they will be unable to meet their payments. Thus a scheme of reclamation that would be not only possible but profitable for a wealthy company or corporation is, under present conditions, well-nigh impossible for the individual landowner of the Imperial area.

The conditions can, however, be at least temporarily improved and the rise of alkali delayed by individual effort. The aim should be to

loosen the heavier soils in every way possible, to assist the natural drainage, and to see that in irrigation all parts of the fields are covered. Irrigation by surface flooding should be the only method of applying water on soils carrying at present a harmful quantity of salts, and for the lighter and freer soils a system of irrigation should be followed that will permit occasional flooding to wash below the surface accumulations that will be inevitable with furrow irrigation.

Moreover, on such soils as those of the Imperial area, in all cases where the harmful amounts of alkali lie in the subsoil and not in the surface, it should be possible so to irrigate, using only enough water to grow grains or other shallow-rooted annual crops, that connection between the subsurface and the irrigation water will not be made, thus preventing the rise of alkali. Such careful irrigation can be continued indefinitely without injury to the land. When the surface 2 feet or so of soil contain an excess of salt, however, or when the salts from below have once risen through the improper application of water, or the rise of the water table, then it is useless to attempt cultivation with the sparing use of water, but the opposite method of thoroughly drenching the land, which has first been provided with adequate sub-drainage, is the only safe and efficient one to follow. The one idea in this method is actually to wash and sweeten the land, dissolving the salts in the irrigation water and carrying them away in solution in the water passing off through the drains. The quantity of salts that can be removed in this way when the soil allows a ready percolation of water, the flooding is heavy, and the drainage system adequate, is astonishing. Means, in Bulletin 21 of this Bureau, points out that in Egypt lands of the heaviest character, containing 8 or 9 per cent of salt to a depth of several feet, with surface accumulations often as high as 40 or 50 per cent salt, are commonly reclaimed sufficiently to grow resistant crops in one year, cotton in two or three years, or corn in four years. In order to accomplish this the drainage water must remove hundreds of tons of salt for every acre of land reclaimed.

Of the 693,696 acres surveyed, 296,256 acres of the level part contain less than 0.40 per cent of alkali. All of this part may be cultivated indefinitely to all the crops suited to the soil and climate, provided care is taken in irrigation and cultivation to prevent a rise of the salts from below. Of the remainder 91,008 acres contain from 0.40 to 0.60 per cent. This amount, while dangerous, may, if carefully flooded, admit of several crops being grown before the ground water is raised sufficiently to injure the land permanently. This acreage of less than 0.60 per cent is alone enough to make of the area quite a wealthy agricultural district, alkali-resistant crops being grown on the worst lands, and other crops suited to the climate on those less alkaline and sandy enough to allow intertillage and the deep penetration of the roots.

It is highly probable, however, that the next few years will see an entirely new system of agriculture for these lands. Date palms for the delta have long been talked of, and the Department of Agriculture is experimenting with these in the southwest, with every indication of success. There is hardly any land on the desert that will not grow these if the climate is suitable, so that this crop may be the ultimate solution of the alkali problem for much of the desert.

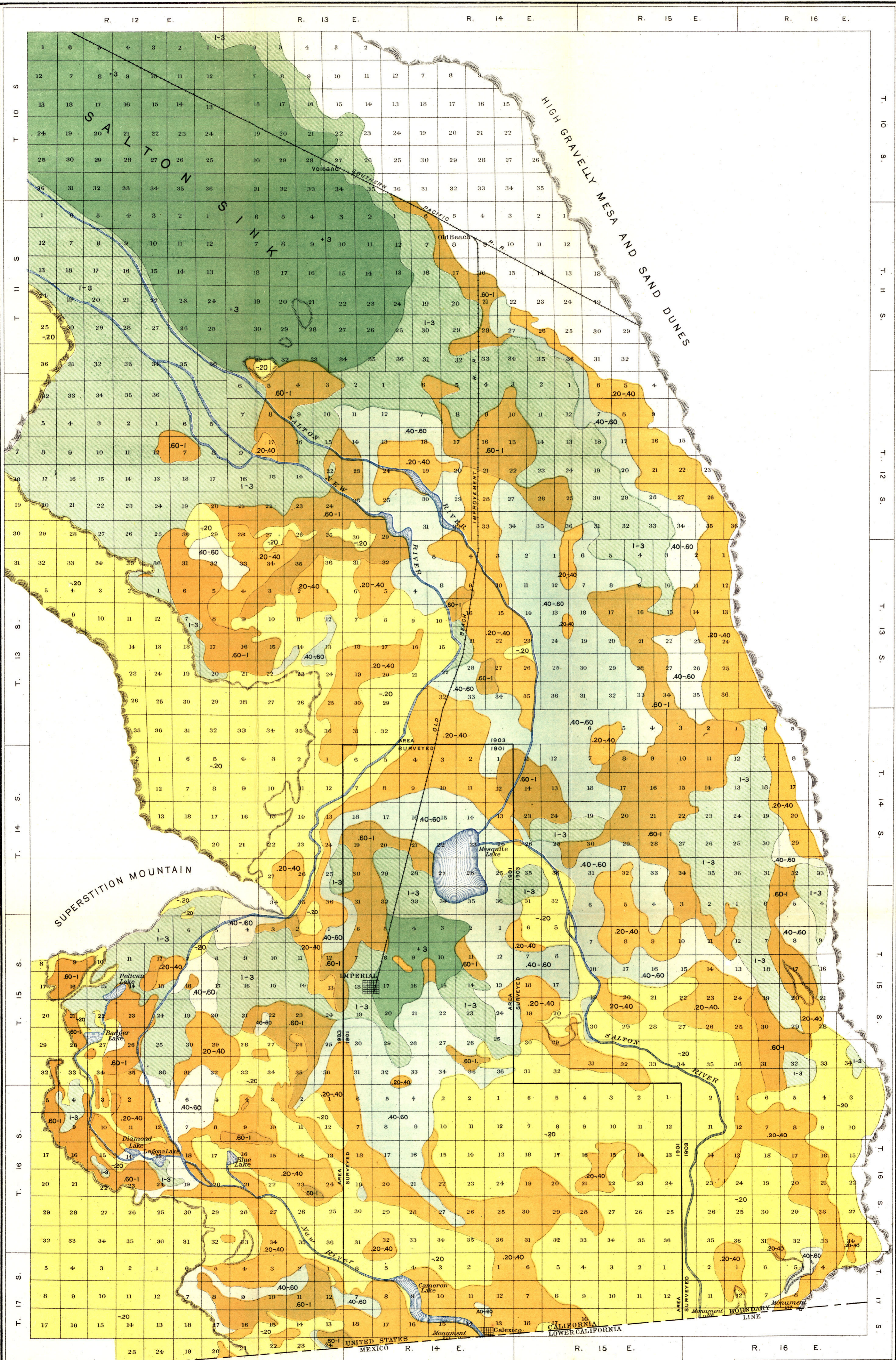
The soil is wonderfully fertile, and irrigated with the sediment-laden water of the Colorado must remain so. The ultimate total reclamation and profitable cultivation of the desert will surely take place. The greatest question at present is one of expediency, namely, How can the reclamation take place and yet protect the present owners from loss? It is believed this can best be done by cultivating at present only the lands that will produce profitable yields of the crops now being grown, and by leaving the badly alkaline lands to be reclaimed when a new system of agriculture has raised the price of land to a point where it will justify the expenditure, and when the need for reclamation has been recognized by everyone interested in the country, so as to secure a complete cooperation of all concerned.

# NRCS Accessibility Statement

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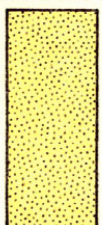


SOIL  
PROFILE  
(6 feet deep)

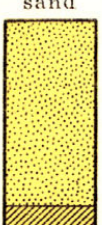
Imperial gravelly loam



Dunesand



Imperial sand



Imperial sandy loam



Gila fine sandy loam



Imperial loam

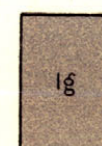


Imperial clay

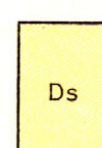


LEGEND  
Ig Gravelly loam  
Ds Sand  
Is Loam  
Isl Sandy loam  
Gsl Clay

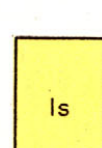
LEGEND



Imperial gravelly loam



Dunesand



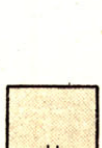
Imperial sand



Imperial sandy loam



Gila fine sandy loam



Imperial loam



Imperial clay

